A glance at the curves will show that the same declination is occupied by different stars at different dates; hence it may happen that the declination found fits more than one star within probable date limits, and so we have to decide which is the more likely star to have been observed. It might at first sight seem that it would be difficult to settle which star is really in question. But in practice the difficulty does not often arise. We now know that the stars used were those in high northern or southern declinations for noting the time at night in the way the Egyptian temples have familiarised us with, and stars nearer the equator to serve as "morning stars," warners of sunrise.

The stars with about the dates already revealed by the work of the last few years may certainly be considered in the first instance.

It is really not a remarkable fact that so few stars are in question, for the use made of them was very definite. Capella, Arcturus, α Capricorni, Pleiades, and Antares almost exhaust the list.

The use of the precessional globe saves many intricate and laborious calculations when only an approximation is required. Thus warning stars at any quarter of the May or solstitial year at any given date may be found by rectifying the globe for the latitude of the place of observation, marking the equator at that date by a circle of water-colour paint by holding a camel's-hair pencil at the east point of the wooden horizon, and rotating the globe. The intersection of the equator and the ecliptic gives us the equinoxes at that date, their greatest separation the solstices. With these data we can mark the required position of the sun on the ecliptic.

This done, if we rotate the globe so as to bring the sun's place 10° below the upper surface of the wooden horizon, the star the rising of which can be used as a warner will be seen on the horizon.

Nor does the use of the globe end here. With a given azimuth, which are all marked on the wooden horizon, the globe may be adjusted to different dates and then rotated until at a certain date a star rises at that azimuth.

NORMAN LOCKYER.

GEODETIC SURVEYS.

THE latest volume (vol. xviii.) of the Great Trigonometrical Survey of India contains the records of astronomical observations for latitude extending over the last twenty years. It is, in effect, the continuation of vol. xi., and brings this particular department of Indian Survey statistics up to date. It consists chiefly of tabulated records; 543 pages alone in part ii. being absorbed by tables of astronomical latitudes. There is therefore nothing to offer in the way of remark or criticism on the great bulk of detail contained in this volume except congratulation on the completion of a work involving so much labour in compilation. It is, perhaps, the most interesting of the whole series of Great Trigonometrical Survey records and the interest of it to the general reader lies in the preface, where Colonel Burrard, in plain and simple language, gives the reasons for the faith that is in him as regards the present position of geodetic work in India.

To those who have pinned their faith to the rigid accuracy of geodetic triangulation as the basis of fixed points for the further extension of minor systems of triangulation and of topographical survey, it may at first sight appear somewhat disturbing to be assured that there is no finality in sight for the value of any fixed point in India, either in latitude, longitude or altitude. Geodetic science can only develop on a system of trial and error. Only by the most rigidly exact systems of measurement possible to human agency can the shape of the earth's figure be precisely determined, and only, when the precise shape of that figure has been determined, can geodetic calculations be satisfactorily computed. Hitherto these calculations in India have been based on an assumed earth-figure known as Everest's spheroid, and although this assumption is not absolutely justified by continuous observation, Col. Burrard rightly maintains that it would be a mistake to break the continuity (and thereby destroy much of the value) of the Great Trigonometrical Survey series by the introduction of tables based on new, and possibly only half-digested, data. Similarly he pleads for absolute accuracy in the determination of latitudes, for it is only when the riddle of the earth's shape shall be solved by the men of science of the future, and the pathway to positive deductions therefrom straightened out, that the full value of this most remarkable body of results (obtained by new and more perfect instruments from observations of stars of which the position is now more certainly known than heretofore) can be effectively utilised

The deflection of the plumb-line forms one of the principal subjects of scientific investigation of which the record is to be found in this book. This deflection is determined by the difference in latitude obtained for any fixed point between the results of geodetic triangulation and of astronomical observation. For reasons already suggested in connection with the assumption of the earth's figure, as well as the fact that the origin of geodetic latitudes in India (at the Kalianpur base) is itself an assumption, there still remains an element of uncertainty in these determinations. They are exceedingly interesting. "In the Himalayas" (which is, perhaps, a slightly vague definition) the deflection amounts to −35.29s.; at the foot of the Himalayas it is −10.90s.; in central India it amounts to +0.94s. But it must be remembered that in dealing with this matter of rigid accuracy we have still to reckon with minutely small errors, quantities that are immaterial for the practical purpose of supplying a basis for map-making. For instance, the most improved methods of observing with the best of new instruments only displaces the assumed value of the Kalianpur latitude by 0.3″. In the matter of longitude there is, however, a recognised error of 2′ 27″, which is an error too large to be neglected. This has to be eliminated from Indian mapping; although, again, Col. Burrard deprecates any interference with the continuity of Great Trigonometrical Survey records in the series ended by this eighteenth volume. To this extent Indian topography and Indian geodesy must remain discrepant for a space of time.

There is, however, one element of disruption in Indian Geodetic Survey work with which no man of science can deal. This is caused by earthquakes, and the resulting displacement of mark-stones is not easily determined. There may be little relative displacement over a large area, whilst the absolute displacement of the whole area may be considerable. It is impossible to re-triangulate the vast spaces which would be necessary to determine this, nor does it appear to be at all easy to discover what may be the effect of such disturbances in altitude. The most careful levelling (three times repeated) over the eighteen miles separating Dehra from Mussoorie only revealed a probable diminution of 5½ inches in the Himalayan altitudes at Mussoorie after the latest, and most violent, earthquake. Meanwhile geodetic science fulfils its mission admirably in the great practical work of establishing the basis for topographical surveys. These never can be affected by those small geodetic adjustments which are all-important to the scientific theorist, although it

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is quite possible that such displacements as are caused by earthquakes might be troublesome to the map-maker. Topography, however, can never be final; never (under some conditions) complete. Col. Burrard, in his admirable preface, aptly quotes the shifting Indus as a case in point. Could the whole Indus valley be surveyed in any one year we could then say "that was the course of the Indus in the year ——." As it is we can never hope to possess an accurate topographical representation of the Indus from the mountains to the sea at any one time—nor does it much matter if we cannot.

The expense and the labour of geodetic triangulation undoubtedly imposes certain limitations on its practical use, and probably no record in scientific history of its misapplication is more remarkable than that which may be found in the Government report on the Boundary Survey between British Bechuanaland and German South-west Africa. Here an elaborate series was extended at a ridiculous cost, and involving the labour of several years, in order to determine the position of a meridian line (running through the Kalahari desert) which had been defined by diplomats in England as the only possible boundary. The possibility of the existence of gold or diamond mines demanded an exact and visible demarcation no doubt; but where that demarcation was carried through the undeveloped and waterless wilderness was not a matter of significance, provided it were somewhere near the defined line. It may be that the meridian (almost the worst boundary definition possible) was without an alternative, in which case a most important word must have been inadvertently omitted from the protocol, or agreement. That word was "approximate." A free use of it in the original definition, and a liberal interpretation of it in the field, would have enabled a topographer to run a plane-table traverse quite sufficiently close to the meridian on a "chronometric" longitude to have fixed up the boundary marks as he proceeded, and so to have completed the whole boundary in, say, one-fifth the time and at one-tenth the expense of the geodetic determination. It is not as if this geodetic determination resulted in rigid (and unnecessary) accuracy. Col. Burrard's preface to his eighteenth volume at once disposes of any such possible pretension; nor is it as if it formed the basis for useful topography, for not a square mile of topography resulted. The only result is a possibly useful basis for the extension of future triangulation in German territory—and for this the German Government should have paid.

T. H. H.

THE RÔLE OF LIQUID CRYSTALS IN NATURE.

THIRTY-SIX years have elapsed since Prof. Otto Lehmann, while a student at Stuttgart, designed a novel form of microscope which permitted of the optical examination of substances at temperatures differing considerably from that of the surrounding air, and thus obtained access to an almost virgin field for research, to the cultivation of which he has strenuously devoted himself. The results of a long series of observations were collected and published in the form of the fine volume entitled "Flüssige Krystalle," which was noticed in NATURE in 1904 (vol. lxx., p. 622). Prof. Lehmann, however, by no means intended that work to constitute his last word on the subject, and, as is testified by the numerous papers which have since that date appeared from his pen in various journals, he has in no way relaxed his efforts in the prosecution of his investigations. Of recent years, moreover, other workers have in greater number been attracted to the subject, and their observations are, on the whole, in harmony with his, and confirm the substantial correctness of the views he has put forward. In particular, mention may be made of Prof. D. Vorländer's extensive investigations of the azoxy-compounds. Although there was in early days, not unnaturally, considerable scepticism regarding the correctness of Prof. Lehmann's observations and the deductions he made from them, there is at the present time little reason to doubt the reality of the existence of anisotropic liquids and the importance of the *rôle* they play.

At first sight it may seem ridiculous and absurd to suppose that any immediate relation can subsist between the properties of liquids and crystallised matter. The study of the characters of crystals has demonstrated that the molecules composing a crystal are regularly arranged at the nodes of the corresponding space-lattice. Such a structure possesses great rigidity, a character incompatible with the mobility of a liquid. It is, indeed, very probable, as Mr. William Barlow suggests, that the spheres of influence of the constituent atoms are all in contact with their immediate neighbours, and the molecule has no separate entity in the crystal. On the other hand, in a gas the molecules have clearly a distinct existence; they are in constant motion, and for the greater part of their course are remote from one another, and, if not kept within bounds in some way, would altogether part company. It is not difficult to suppose that a liquid may be a compromise between such different states; it may retain, though to a lesser degree, both the regularity of the solid and the mobility of the gas. That extreme rigidity is not an essential property of a crystalline structure is evinced by certain minerals—mica being a conspicuous example—which are susceptible of considerable bending without permanent derangement of the structure. Solid substances break when the limit of elasticity is reached, or, in other words, when no further slipping of the spheres of influence upon one another is possible without a collapse of the equilibrium. There are, however, substances with small rigidity in which a greater amount of shear is possible; to these viscous substances, of which the melted modification of silver iodide is a familiar instance, Prof. Lehmann applied the term "fliessende Krystalle." Finally there are substances with almost negligible rigidity in which so much relative slipping is possible without a collapse that, though anisotropic, they are as mobile as water; these he has called "flüssige Krystalle."

No sharp distinction can, however, be drawn between the three groups. Indeed, one curious substance, the ethyl *para*-azoxycinnamate, has been discovered which is solid in the direction of the principal axis, but fluid at right angles thereto. Further, some substances, such as cholesterylcaprinate, have two liquid modifications. Certain of them—*para*-azoxyanisol, for instance—become turbid on melting, but on increased heating suddenly clarify at a definite temperature. The turbid liquid was at first supposed by many physicists to be an emulsion; but recent investigations by Dr. R. Schenk and Dr. A. C. de Kock indicate that the turbid liquid is a homogeneous phase. The mutually repulsive action—possibly an electromagnetic phenomenon—that characterises the molecules of a gas takes in a liquid the form of an "expansion-force," as it is termed by Prof. Lehmann. This force varies in different directions according to the symmetry of the molecule, and consequently the envelope of the liquid crystal, as seen in the microscope, is polyhedral, the corners being rounded owing to the effect of surface-tension. The contour is circular when the expansion-force is nearly

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